Lunar Reconnaissance Orbiter: (Mini-RF)

Audience
Grades 6-8

Time Recommended
1-2 Hours Pre-Lab activities; 1-2 hours Lab activities

AAAS STANDARDS

- 1B/1: Scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.
- 3A/M2: Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information.
- 12D/M10: Understand oral, written, or visual presentations that incorporate circle charts, bar and line graphs, two-way data tables, diagrams, and symbols.

NSES STANDARDS

Content Standard A (5-8): Abilities necessary to do scientific inquiry:

c. Use appropriate tools to gather, analyze and interpret data.

d. Develop descriptions and explanations using evidence.

e. Think critically and logically to make relationships between evidence and explanations.

Content Standard E (5-8): Science and Technology:

b. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigation, inquiry, and analysis.

MATERIALS

- Pre-lab worksheets (included)
- Lab worksheets (included)
- Set of Clementine images (included)
- Corresponding Mini-RF data (included)
- Dry erase markers
- Clear overhead transparencies
- Lunar Landforms Definitions with Associated Images sheet (included)
    - » NOTE: When printing images, be sure to print as high of a resolution as possible

Mini-RF: Using Radar to Search the Darkness

Learning Objectives:

- Using Mini-RF data, participants will learn how the Mini-RF can identify lunar surface features that are permanently shadowed, or lack any visible evidence of surface morphology.

Preparation:

See procedure section for specific details regarding each activity.

Background Information:

An instrument onboard the Lunar Reconnaissance Orbiter (LRO) called Mini-RF is searching for something special. People have been gazing and wondering about the Moon for millennia, but it still holds many mysteries. Until recently, we haven't been able to see into places such as permanently shadowed craters on the lunar surface. Mini-RF is helping scientists look into regions never before seen to make new discoveries about our Moon.

One of the things scientists are searching for is water. While the samples of lunar rock that were returned by Apollo were dry, there is evidence that water ice may exist inside impact craters near the cold lunar poles. This water ice would have been delivered to the Moon, over billions of years, by multiple impacts of comets and asteroids.

It is theorized that the interiors of permanently-shadowed craters near the poles are so cold that any water molecule entering would be unable to escape. Mini-RF will use radar to "look" inside these craters to search for any ice present. These ice deposits could be a valuable resource for a future human outpost, since such exploration is expensive.

Over the years, several missions have done their part in searching for water on the Moon:

1. The EPOXI mission (http://epoxi.umd.edu): During its journey to the Tempel 1 comet, the Deep Impact spacecraft focused its instruments on the Moon in June 2009, where it revealed evidence for the presence of water on the lunar surface.

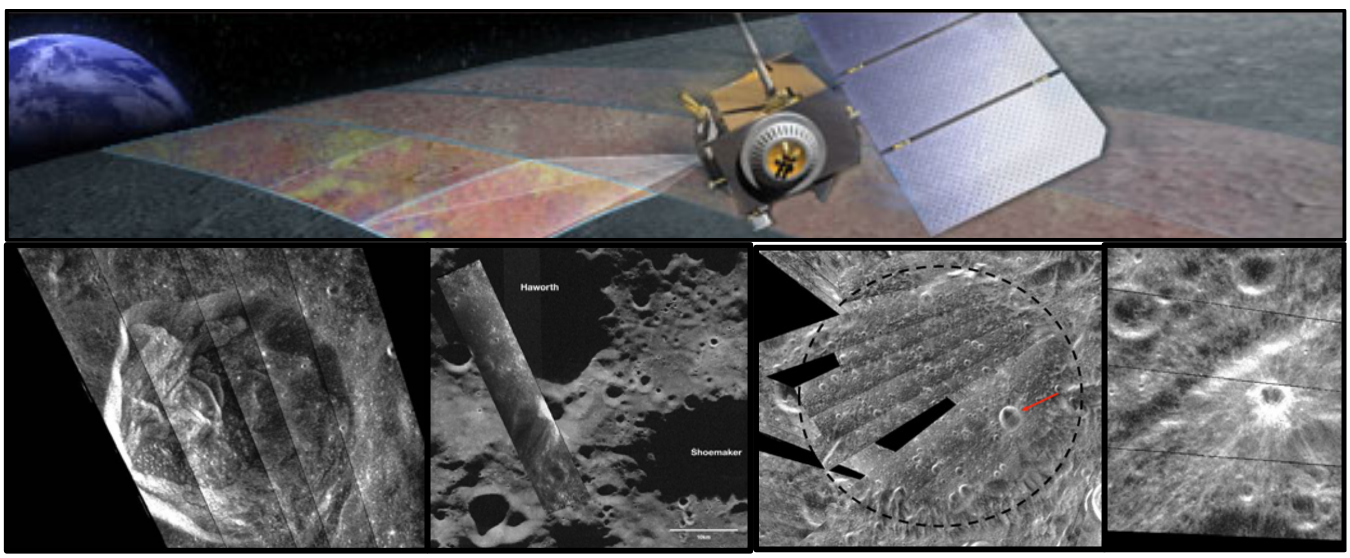
2. Chandrayaan-1 (M3) mission (http://m3.jpl.nasa.gov): The Moon Mineralogy Mapper (M3) is one of two instruments contributed by NASA to India's first mission to the Moon, Chandrayaan-1. M3, a state-of-the-art imaging spectrometer, has provided the first mineralogical map of the lunar surface at high spatial and spectral resolution. By analyzing the data, scientists are determining the composition of the surface of the Moon. Data collected indicated molecules of water in trace amounts.

3. Apollo sample return discoveries: In rock samples that were returned from the Moon during the Apollo missions, scientists found trace amounts of water.

4. LCROSS: (http://www.nasa.gov/mission_pages/LCROSS/main/index.html) The impact plumes of the Lunar Crater Observation and Sensing. LCROSS and its Centaur rocket stage in Cabeus crater near the south pole of the Moon on Oct 9, 2009 showed the spectral signature of hydroxyl, a key indicator that water ice is present in the floor of the crater.

The discovery of water ice on the Moon has enormous implications for a permanent human return to the Moon. Water ice is made up of hydrogen and oxygen, two elements vital to human life and space operations. Lunar ice can be mined and disassociated into hydrogen and oxygen by electric power provided by solar panels deployed in nearby illuminated areas or a nuclear generator. This hydrogen and oxygen on the Moon is a prime rocket fuel, giving us the ability to refuel rockets at a lunar "filling station" and making transport to and from the Moon more economical by at least a factor of ten. Additionally, the water from lunar polar ice and oxygen generated from the ice could support a permanent facility or outpost on the Moon. The discovery of this material, rare on the Moon but so vital to human life and operations in space, will make our expansion into the solar system easier while reaffirming the immense value of our own Moon as the stepping stone into the universe.

Mini-RF also allows scientists to gain more information about the surface and subsurface of the Moon, including the far side we never see from Earth. Mini-RF also allows scientists to get a better feel for surface properties and the composition of the Moon, essentially bridging the gap between past research and current technologies.



Procedure:

See each student lesson located in the worksheets section for the corresponding procedure. There are pre-lab and lab worksheets to choose from related to the Mini-RF.

worksheet

PRE-LAB ACTIVITIES:
How We Use Radar to See

Name ______________________________

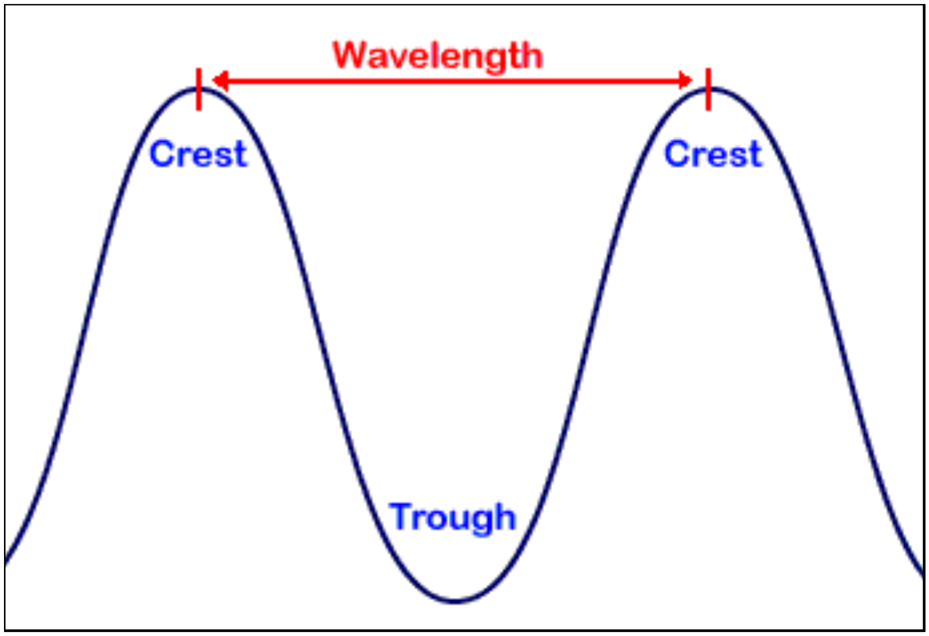
We're used to seeing images of Earth or the Moon or any planetary body using ordinary cameras that see things the same way our eyes do: with visible light provided by the Sun or by a flash. But radar uses microwaves (energy with a longer wavelength than light) which also reflects off the surface being imaged. But, because it uses energy in a region of the electromagnetic spectrum that has longer wavelengths, it can do things that ordinary cameras can't: radar can show features that we can't see with our eyes.

Pre-Lab Activity Part 1— Seeing Through the Smoke

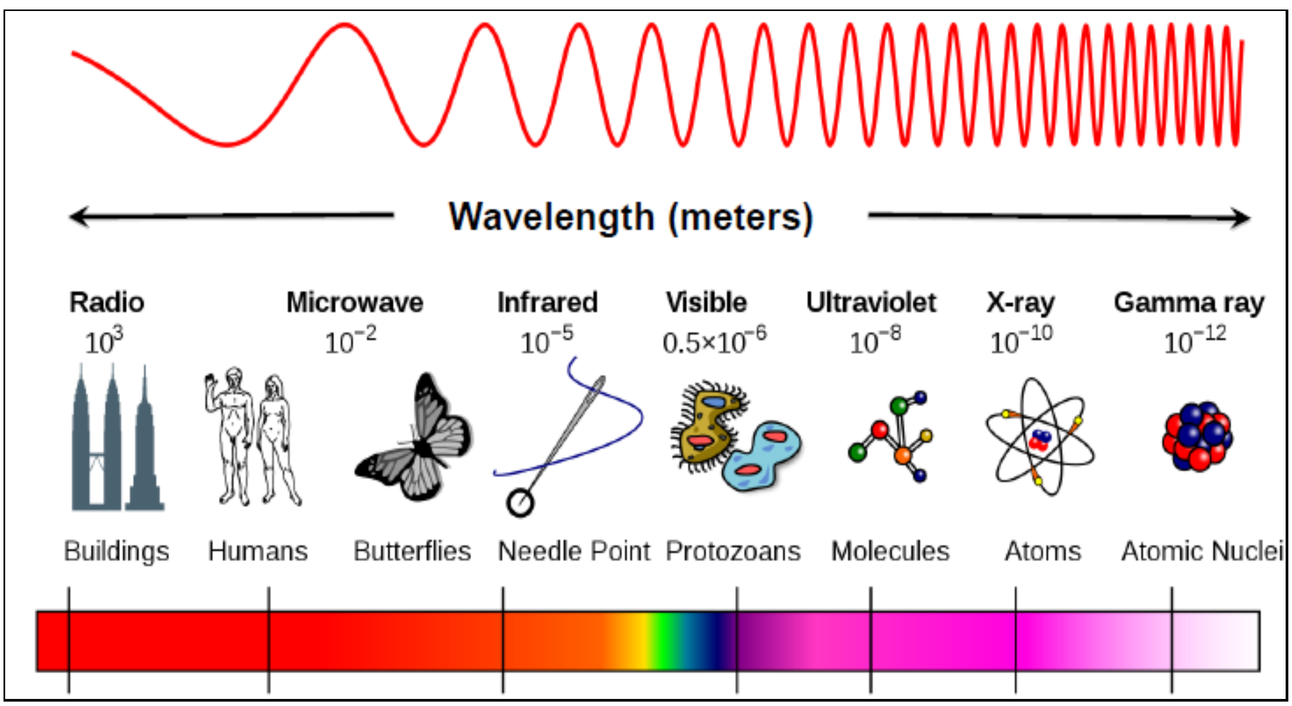
To give you an idea of how this works, let's look at a few images taken from space using radar.

These side-by-side images of the same volcanic eruption show the differences between optical imaging and radar imaging. On the left is a photograph taken by space shuttle astronauts as the shuttle Endeavor passed over the eruption of Kliuchevskoi volcano in Kamchatka, Russia. On the right is the radar image acquired by the SIR-C/X-SAR radar instrument. In the photograph, the ash plume is emerging from a vent on the north flank of Kliuchevskoi. In this view, the volcano is partially hidden by the ash plume and its shadow. The radar image shows how radar can see through the ash and smoke to reveal the contours of the land underneath.

So, how does radar "see" through the smoke and haze? It all has to do with wavelength. As energy radiates out from a source, it travels in a wave. All radiation can be described in terms of energy or what we can also call wavelength. Wavelength is the distance from one wave crest to the next wave crest:



The range of all possible wavelengths is called the electromagnetic spectrum:

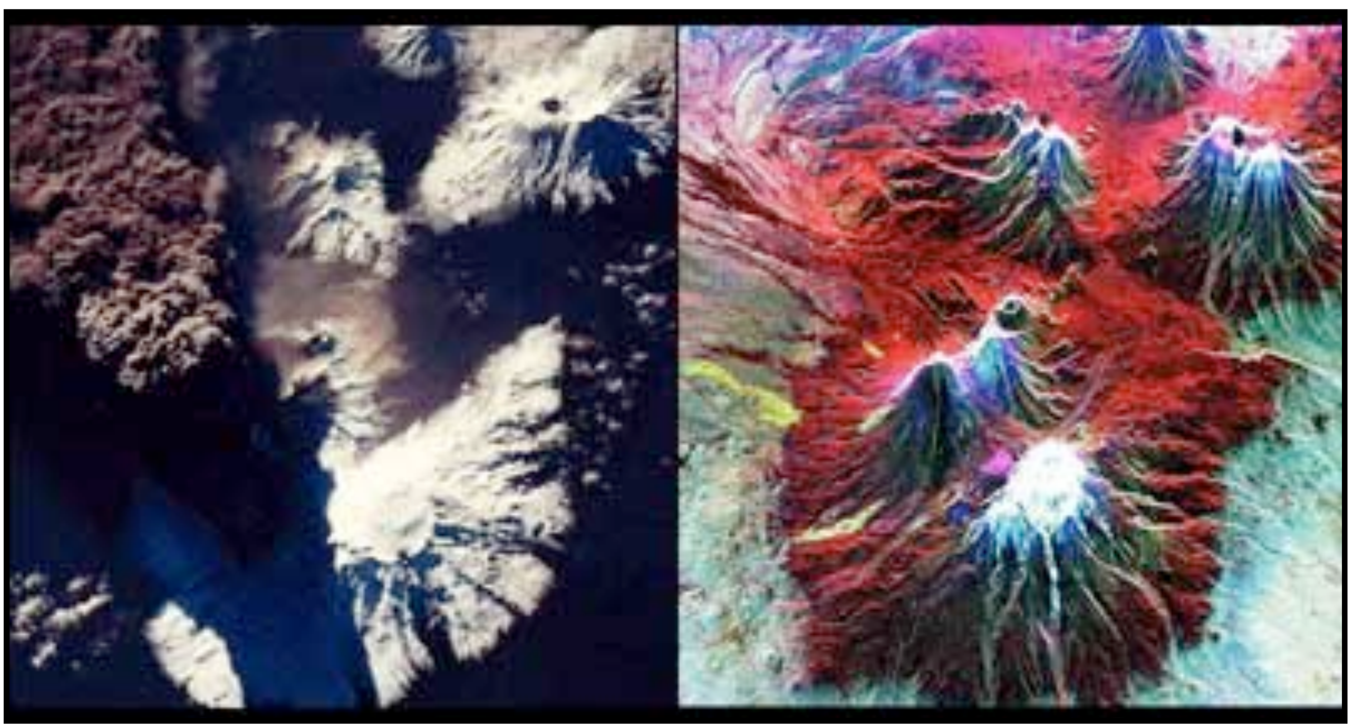


Our eyes can only detect radiation from a very small portion of the electromagnetic spectrum (from about 400-700 nanometers). Because visible light has such a small wavelength, it has a tendency to bounce off every object, including smoke particles and water droplets in a cloud. By the time it is transmitted through the smoke or rain, it has been scattered too much. Radar on the other hand has such a longer wavelength compared to visible light, it doesn't reflect or bounce around water droplets or smoke particles. Thus, radio waves can enter and exit the clouds relatively undistorted, allowing scientists to see through them.

Visible light contains a range of wavelengths, but with radar we often measure one very specific wavelength. Just think of how differently things would look if you could only see yellow. Your eyes would only detect how brightly an object scattered yellow, so the reflection's intensity, not the color, is what would give you new and useful information.

Similarly, radar antennae are often made to detect how brightly objects reflect one particular wavelength. Since there are no other "colors" (wavelengths) to mix in, we really only care about the backscatter's intensity and therefore scientists will often use grayscale when showing surface features.

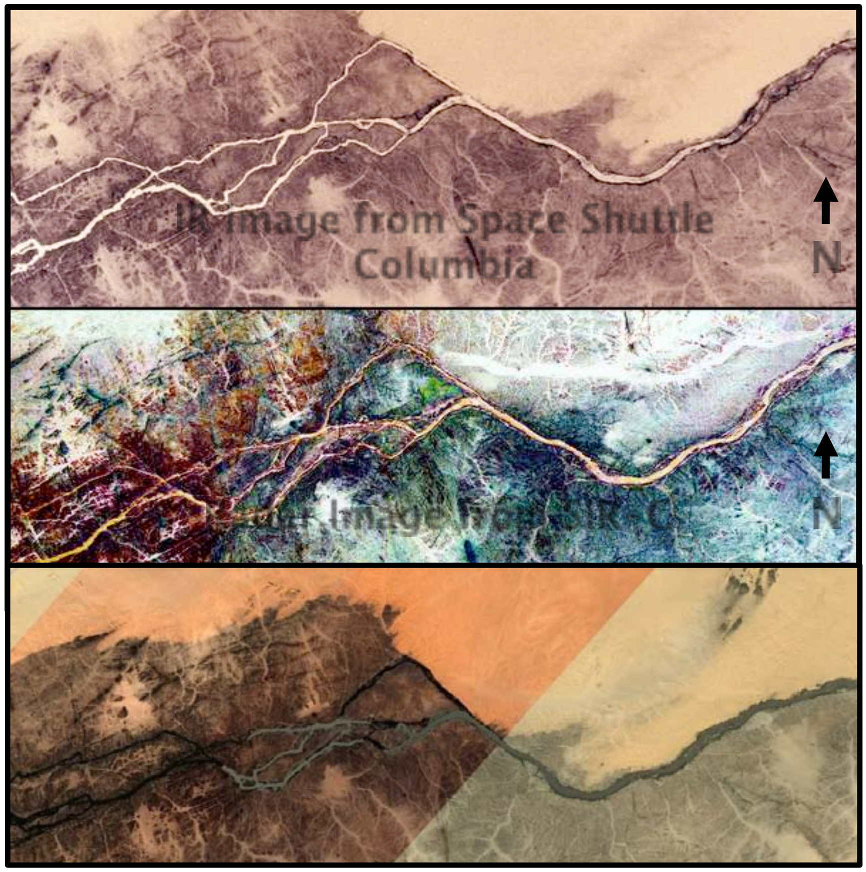
Look at both images of the volcano. What are three features you can see in the radar image, that are hidden in the visible image?



Name ____________________________________

How Radar Unmasks a Surface

Pre-Lab Activity Part 2—Revealing Ancient Rivers



These are three views of parts of the Nile River, near the Fourth Cataract in Sudan, Africa. The top image is a photograph taken with color infrared (IR) film from space shuttle Columbia in November 1995.

The middle is a radar image that was acquired by the Spaceborne Imaging Radar C/X-Band and Synthetic Aperture Radar (SIR-C/X-SAR) aboard space shuttle Endeavour in April 1994.

The third image is a visible image from Google Earth from 2010. The thick, white band in the top right of the radar image is an ancient channel of the Nile that is now buried under layers of sand. This channel cannot be seen in either the IR photograph or the visible image. Its existence was not known before the radar image was processed.

The area to the left in all the images shows how the Nile is forced to flow through a chaotic set of fractures that causes the river to break up into smaller channels. Because radar can penetrate below the surface of the sand to a certain depth, scientists can see where the river used to be and where it is today. Scientists estimate that probably sometime between 10,000 and 1 million years ago, the Nile was forced to abandon its bed and take up a new course to the south. (http://www.jpl.nasa.gov/news/releases/96/sirnile.html) The radar images have allowed scientists to develop new theories to explain the origin of the "Great Bend" of Nile in Sudan, where the river takes a broad turn to the southwest before resuming its northward course to the Mediterranean Sea. As you can see, radar allows scientists to uncover features they would never have seen before, and gave them a new tool to understand the complexities of this feature. Mini-RF does the same thing for scientists, allowing them to peer into areas that are either completely hidden by ejecta from a crater or peer into the darkness of a shadowed crater.

Student Exercises

1. How could we use what we learn from this above image to help establish agricultural areas along the Nile? Using the radar images, how could scientists track future changes to the path of the Nile?

2. List ways that radar images from space can give us information needed to help manage and solve environmental issues on the Earth and possible landing sites on the Moon.

Earth:

Moon

Using Radar to “see” the Moon—Intro

As we have seen in previous images, radar allows scientists to view areas of a planet that are covered by the ground, foliage, and even clouds. If radar allows scientists to see hidden objects, then it can be used to peer into dark, unlit regions as well. This is where the Mini-RF instrument comes in. Mini-RF not only allows scientists to see dark regions, but it allows scientists to view hidden features, which are typically hidden from view.

Images from the Mini-RF instrument, (a lightweight, Synthetic Aperture Radar or SAR), show the floors of permanently shadowed polar craters on the Moon that aren’t visible from Earth. With the data acquired from the poles, scientists are looking for evidence of water ice. With the data they acquire from non-polar regions, they are looking at ejecta patterns, tectonic features and compositional effects of impact craters on the surface of the Moon.

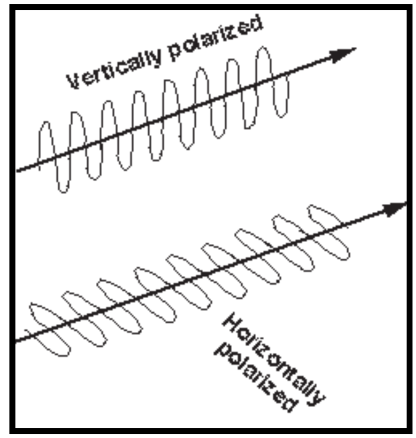
Look at the image to the left, which was taken of an area near the south pole of the Moon. Several areas at the south pole never see sunlight and are permanently shadowed, like Haworth crater. The long rectangle in the middle is a Mini-RF radar image placed over the top of a larger Moon surface image that was taken from an Earth-based telescopic image. The Mini-RF image, taken in 2009, reveals a part of the shadowed crater never seen before. This type of imaging (using radar) helps scientists explore these permanently shadowed regions.

In this image, bright areas represent surface roughness or slopes pointing toward the spacecraft. The data strip covers an area approximately 50 kilometers (31 miles) by 18 kilometers (11 miles).

Once Mini-RF takes images of the surface of the Moon, the image can then be overlaid onto a visible image, which may then reveal areas which are completely obscured to the human eye.

worksheet

Polarization



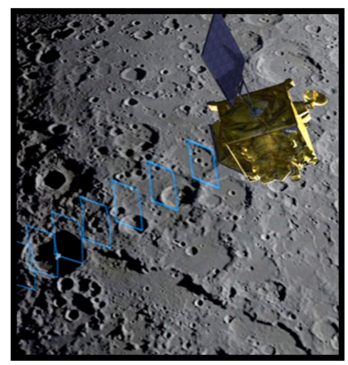
As mentioned previously energy travels in waves. Visible light for example travels at all angles as it moves. This movement is in many different directions, but we can isolate certain movements compared to other movements (i.e. vertical versus horizontal movement). Polarization is the phenomenon in which waves of light or other radiation are restricted in a certain direction. Think of a rope that you pull through a picket fence. If you hold one end of the rope and someone holds the other end, and you move it up and down like a wave, the wave can travel right through the vertical pickets. But, if you try to make a wave side to side, only some waves may get through, while others are blocked. This is an example of polarization.

As you can see in the example to the right, vertically polarized waves travel in a vertical fashion, where as horizontal waves travel horizontally.

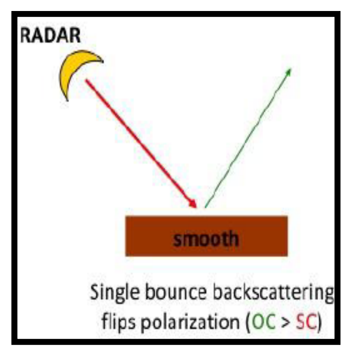
What Does This Have To Do With Radar?

Mini-RF sends pulses of radar that are polarized. It transmits radar signals to the surface of the Moon and oscillates in a circle as it goes along (like a slinky or a spring). Typical planetary surfaces reverse the polarization during the reflection of radio waves, so that normal echoes from Mini-RF are right, circular polarized (this measurement is called the Circular Polarization Ratio or CPR).

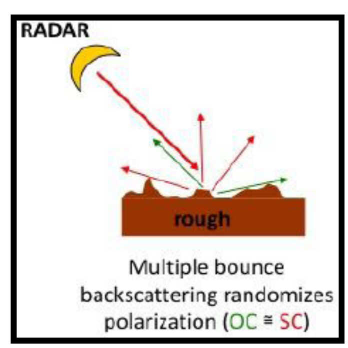
Let's detail how Mini-RF analyzes a signal:



Step 1: When Mini-RF sends the radar signal down to the surface (it is spinning in a certain direction— i.e. left circular, or counter clockwise). When the light hits the surface, it bounces off and some reflects back to the instrument. Think of it like a bicycle reflector spinning and reflecting light back.



Step 2a: If the signal from the surface of a planet returns spinning in the opposite direction of the sent signal, then the signal is said to have opposite polarization. This indicates that the surface is smooth. In Mini-RF images, these smooth areas would appear dark. Scientists us the abbreviation "OC" to mean the polarization returning from the surface is opposite polarization compared to when it left the instrument. "SC" means it returns as the same polarization.



Step 2b: The signal returned from the lunar surface is called the radar "backscatter". When the surface is rough, the signal is scattered in many different directions, including back towards the radar receiver. In Mini-RF images, these rough areas would appear bright. When the surface is smooth, the signal is primarily scattered in one direction, away from the radar receiver. In Mini-RF images, these smooth areas would appear dark.

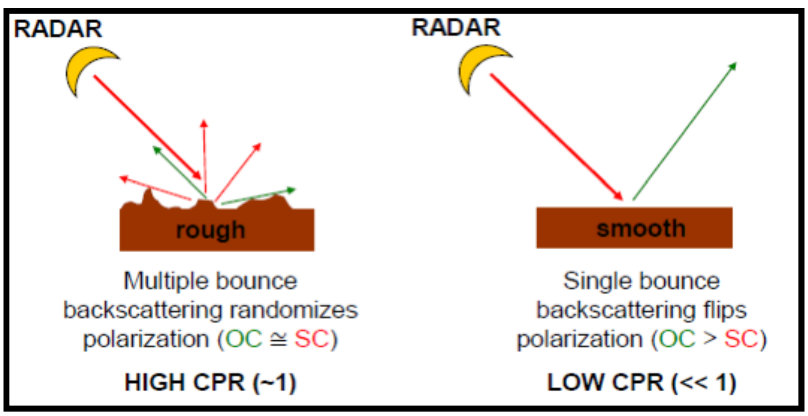
The radar signal is transmitted with a certain polarization (you can think of the radar wave as spinning through space in a clockwise direction). This polarization – the "same-sense" that was transmitted – is flipped when it bounces off a surface, and takes on the "opposite-sense" polarization (a wave that is spinning through space in a counter-clockwise direction). On a rough surface, the signal will bounce several times before returning to the receiver. This "randomizes" the polarization that is received by the radar, so the signal is roughly equal parts, or "same-sense" and "opposite-sense." On a smooth surface, the signal will generally bounce only once, producing a return with mostly "opposite" polarization. When you compare the ratio of "same-sense" polarization to "opposite-sense" polarization, it will therefore be high for rough surfaces, and low for smooth surfaces.

CPR: Circular Polarization Ratio

Once scientists have determined the polarization of the signal, they can then measure how much a signal has been reflected back to the spacecraft, or how much of it has been scattered, putting these numbers into a ratio called a circular polarization ratio, or CPR.

If there is more "opposite sense—OC" than "same sense—SC" of a polarized signal reflected back to the spacecraft, then the surface is said to have a "low CPR" or low Circular Polarization Ratio. In science terms, this means a surface is smooth. Here is the ratio: **CPR = SC/OC**

If the OC and SC are very similar (meaning the surface equally reflects back the same signal and opposite signal) then it is said to have a "high CPR" or high Circular Polarization Ratio. Again, in science terms, this means the surface is rough, and should be looked at more closely. A high CPR could mean the area is a rough, rocky terrain, or it could mean there may be ice causing the light to scatter. Using the empty box below, create a "reference box" similar to the one you see here:



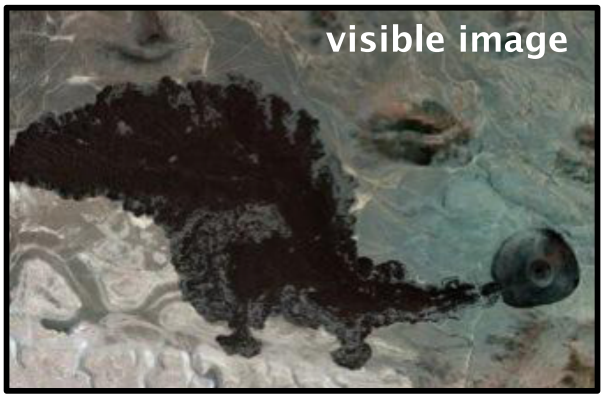
Student "Reference Box"

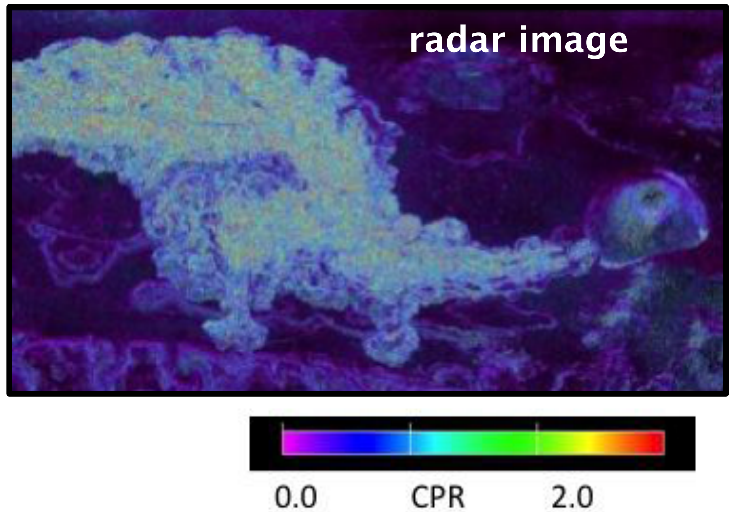
Name ____

Difference Between Radar and Visible Light

Pre-Lab Activity Part 3—Image Analysis

Take a look at the color radar image below. This is an image that was taken of a volcano in northern Arizona. Compare the visible image with the radar image on the right.





1. What do you notice about the difference between the two images?

2. Next, take a look at the color bar. From what you understand about High CPR (rough areas) and Low CPR (smooth areas), what is the one thing you can determine about the brightly colored area in the radar image?

3. Could you tell in the visible image if the dark region is smooth or rough? Why or why not?

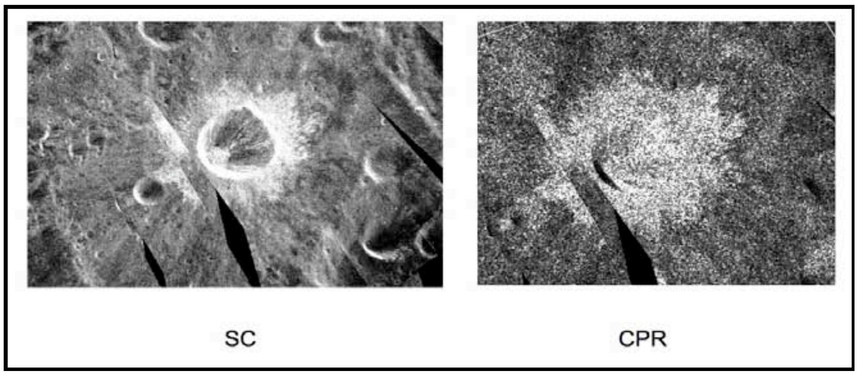
4. What does water ice look like to radar? How can we tell if it might be there? When scientists compare the high CPR images, (indicating a rough surface) with images that are visually smooth, then something else must be present. A likely possibility of water ice!

Additionally, when scientists compare the Mini-RF images with terrain that is known to be older or younger, this helps the scientists know whether there is a strong possibility of water ice there. “Newer” craters are more likely to be blocky and rough, whereas “older” craters are more worn, so we expect them to be smooth. If we find an older crater with a high CPR (normally indicating a rough surface) that indicates there is a good chance ice is there.

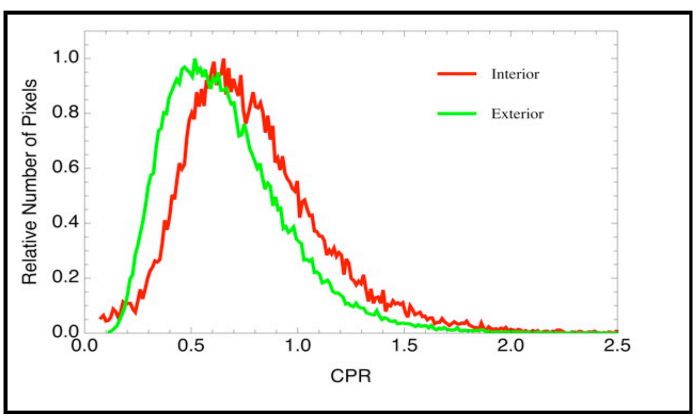
What does water on the Moon look like?

The images below (all radar images) show how scientists search for evidence of water on the Moon. This first image shows no signs of water, simply rough areas on the Moon. How can we tell?

First, let’s take a look at the image. In the two images below, one is labeled “SC” (same sense) and the other is “CPR” (Circular Polarization Ratio). Remember, bright areas indicate a rough surface. The SC image indicates the brighter areas that would indicate to scientists that those areas are rough. Now, look at the “CPR” image. When scientists compare both images, we see that the SC and CPR images show very similar patterns of white, which indicates that we are looking at ejected material onto the surface after the impact.



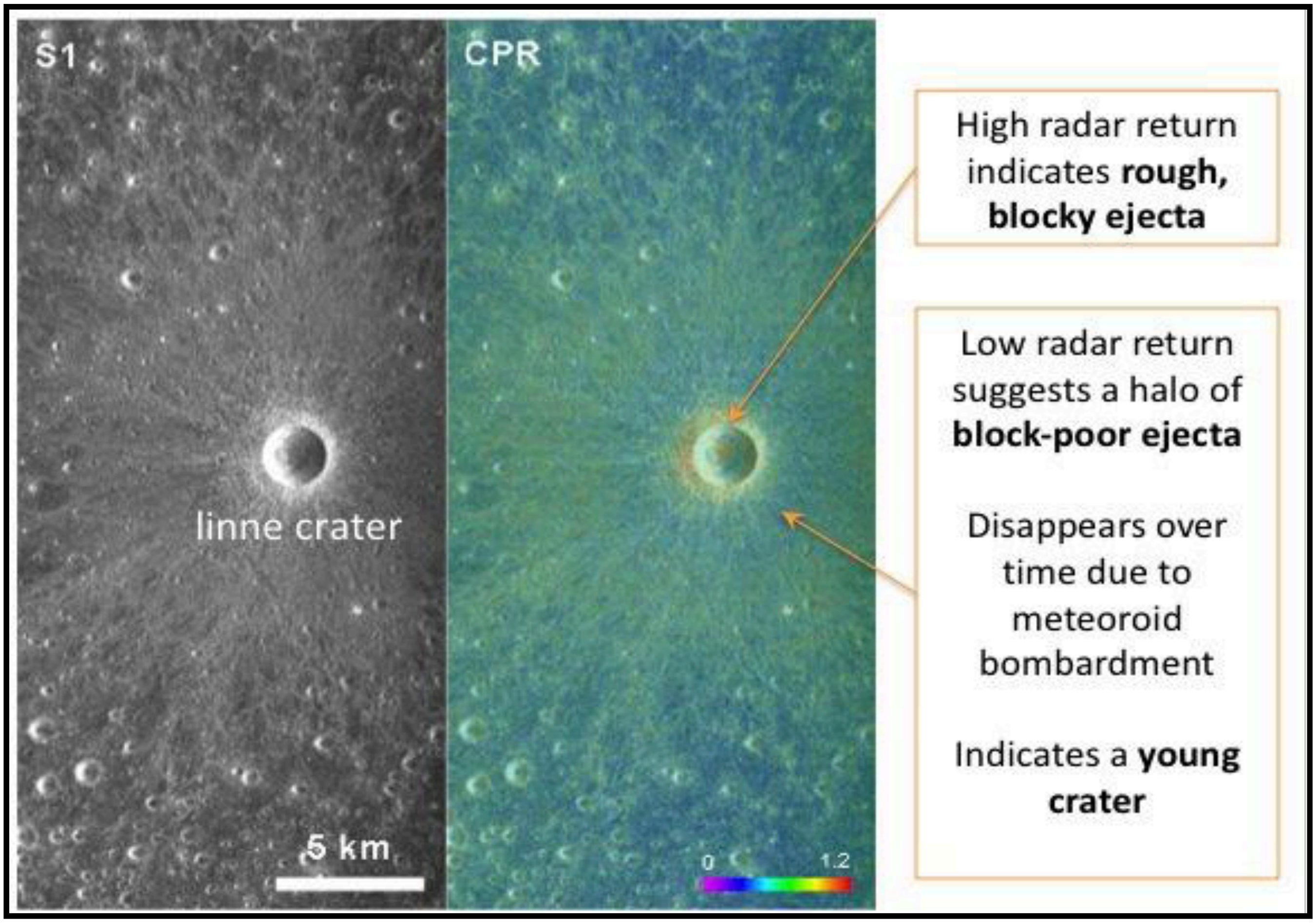
Next, scientists can take the data from Mini-RF and graph it as seen below with the red and green lines. They compare the high CPR values (or white in the image) inside and outside the crater rim. The red line is the interior of the crater and the green line is the exterior of the crater. By graphing the data, they can see the values both inside and outside the crater are almost the same. Graphically speaking, the white in the images indicates a rough, rocky surface.



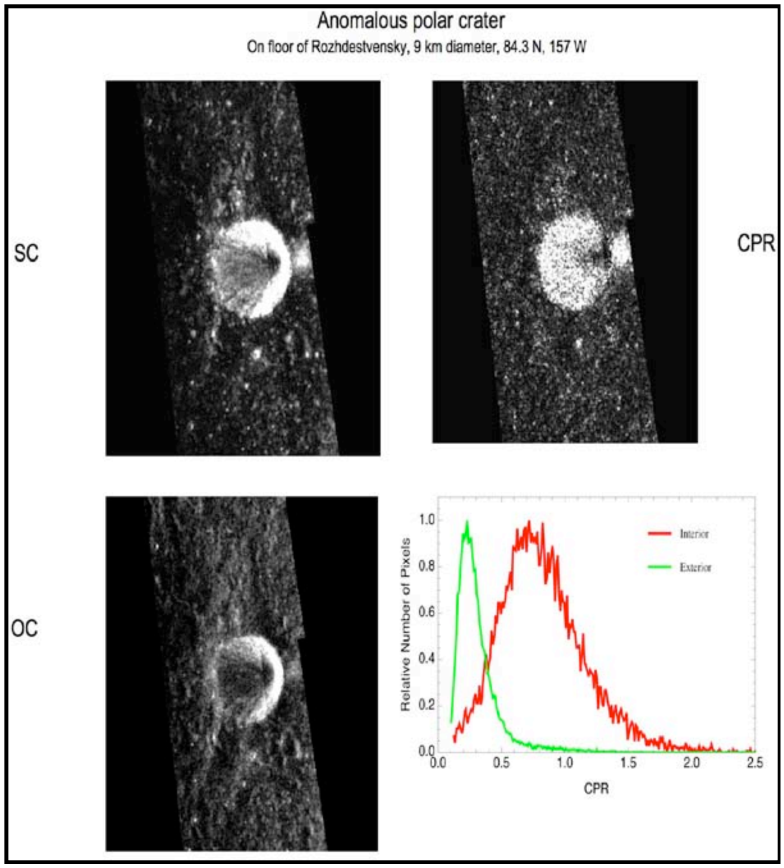
worksheet

Here is another comparison of radar images. The false-color helps scientists determine the level of CPR in the image on the right.

In the image to the left, you can see similar correlation between image on the left and the high CPR readings around the outside of the crater. This indicates a rough surface. Other details are also provided to show how scientists can analyze even more information when looking at CPR data.



The picture to the right shows a crater on the floor of Rozhdestvensky near the north pole of the Moon. This feature shows high CPR within the crater rim but low CPR outside, suggesting that roughness, which occurs throughout a fresh crater, is not the cause of the elevated CPR.

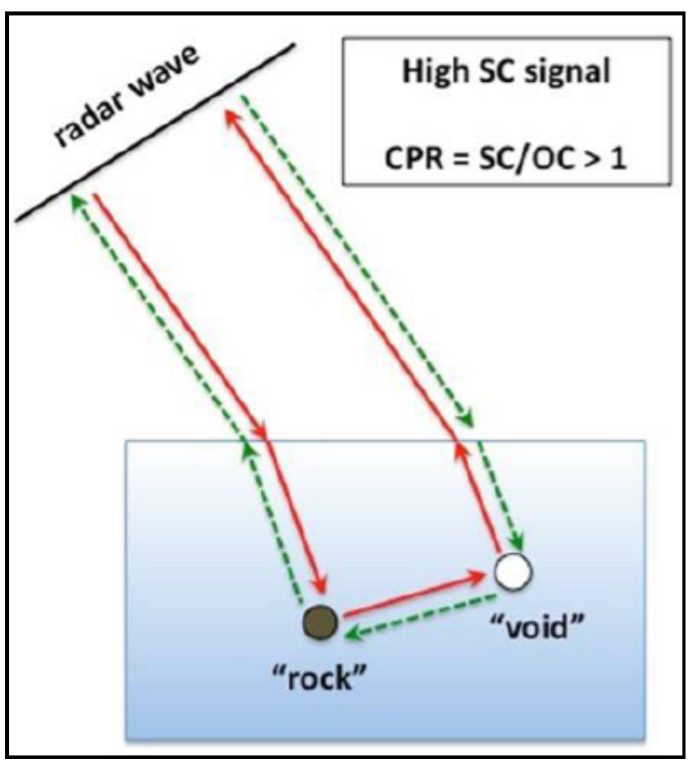


How do scientists know the high CPR levels inside the crater might indicate ice?

First of all, this feature's interior is in permanent sun shadow. Because this area is in permanent shadow, the sun never shines on the dark areas of the crater, and doesn't ever heat the surface.

Secondly, when scientists compare the values the CPR readings, they can clearly see that interior points (red line) have higher CPR values than those outside the crater rim (green line). When they see that the CPR readings indicate that the crater floor is rougher inside the crater than on the outside, this could indicate something else that is causing the reading other than blocky terrain.

In ice (as seen in the image below), two radar signals will follow the same path in opposite direction. These signals add to produce very bright radar returns. Unlike normal radar returns, these signals maintain the original polarization of the radar wave, leading to large same sense (SC) returns, and high circular polarization ratios (CPR).



worksheet

LAB ACTIVITY PART 1

Comparing Visible and Radar images

Materials:

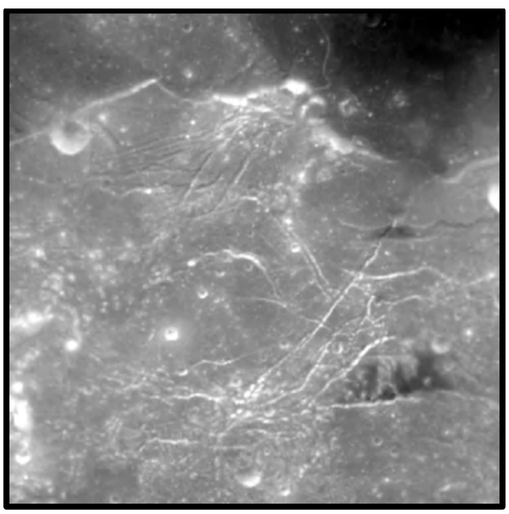
- Visible images of the surface of the Moon
- Mini-RF image strips taken of the same region
- Dry erase markers
- Clean overhead transparencies

Procedure:

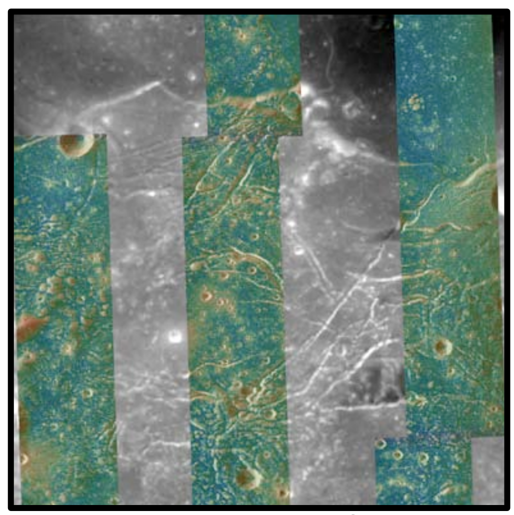
Dark areas on the surface of the Moon can indicate different things. Not only does radar help us peer into permanently shadowed areas on the Moon, it also helps us analyze other features.

By analyzing the Mini-RF image and overlaying that on a visible image of the Moon, scientists can gain a better understanding of what is happening on the surface of the Moon that visible images may not otherwise reveal.

Let's take a look at the example images provided (use the larger **Orientale Basin** images for better resolution):



Clementine mosaic of Orientale Basin



Clementine mosaic of Orientale Basin with Mini-RF overlay

Notice the color in the image on the right. This color enhancement allows scientists to see the different features with more clarity than just simply looking at a black and white image. The blues are low CPR and reds are high. Remember: high CPR suggests a 'rough' surface.

So, let's review (refer to the information above): how do scientists figure out what is high CPR and what is low CPR?

LAB ACTIVITY PART 2

Analysis of Orientale

Name ______________________________________

Materials:

- Dry erase markers
- “Context for Orientale Basin” image (see supplemental materials section)
- “Orientale Basin image with Mini-RF data” image (see supplemental materials section)
- Clear overhead transparency
- Tape (blue painter’s tape works well)
- Lunar Landforms and Associated Images sheets (see supplemental materials section)

Procedure:

1. Now, let’s do some analysis: taking note of the color, list three surface features you can see with the Mini-RF overlay image that you can’t see in the black and white Clementine image:

    a.

    b.

    c.

2. Next, place a clean overhead transparency over the image “Orientale Basin with Mini-RF Data”. Tape the corners so the transparency doesn’t move.

3. Using the dry-erase markers, make notes on the image that show geologic features (lava tubes, craters, maria, lava flows, etc. Also note areas of high CPR, low CPR, and what that could indicate).

4. Using the information you noted on the image, list what you think the geologic history might have been in this area:

worksheet

LAB ACTIVITY PART 3

Name ___________________________

Analysis of additional images (optional: Humboldt Crater)

In this activity, you will practice techniques learned in Activity 2 by analyzing additional lunar surface images. You will be using the image "Humboldt Crater". Identify features and try to determine the geologic history of the areas using your new analysis skills.

Materials:

- Dry-erase markers
- "Context for Humboldt Crater" image (see supplemental materials section)
- "Clementine Mosaic—Humboldt Crater" image (see supplemental materials section)
- "Clementine Mosaic with Mini-RF data overlay" image (see supplemental materials section)
- "Mini-RF data Magnified—Humboldt" (see supplemental materials section)
- Clear overhead transparency
- Tape (blue painter's tape works well but something else will suffice)
- Lunar Landforms and Associated Images sheets (see supplemental materials section)

Procedure:

1. Similar to what you did in the previous activity, list 3 surface features you can see with the Mini-RF overlay image that you can't see in the black and white Clementine image.

    a.

    b.

    c.

2. Next, place a clean overhead transparency over the image "Clementine Mosaic with Mini-RF data overlay". Tape the corners with clear tape so the transparency doesn't move.

3. Using dry-erase markers, make notes on the image that show geologic features (lava tubes, craters, maria, lava flows, etc). Also, note areas of high CPR, low CPR and what that could indicate.

4. Next, using the 2 images "Mini-RF data Magnified—Humboldt", try to match the part of the Mini-RF data strip these images came from.

worksheet

5. Once you have identified the location, list three distinct geologic features you can see within these magnified images:

   a.

   b.

   c.

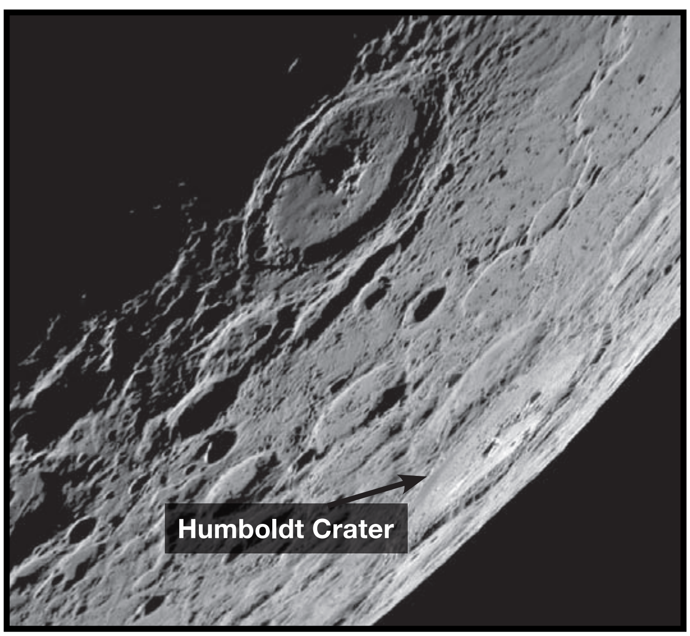
6. Using the information you noted on the image, list what you think the geologic history might have been in this area:

worksheet

LAB ACTIVITY PART 3
Image Descriptions

Orientale Basin Description:

It is over 3 billion years old, about 965 kilometers (600 miles) across and was formed by the impact of an asteroid sized object. The collision caused ripples in the lunar crust resulting in the three concentric circular features visible in this 1967 photograph made by NASA's Lunar Orbiter 4. Molten lava from the Moon's interior flooded the impact site through the fractured crust creating a mare. Dark, smooth regions on the Moon are called mare (Latin for sea), because early astronomers thought these areas might be oceans.



Humboldt Crater Description:

Humboldt is a large lunar crater that is located near the eastern limb of the Moon. Due to foreshortening, this formation has an extremely oblong appearance. The actual shape of the crater is an irregular circle, with a significant indentation along the southeastern rim where the prominent crater Barnard intrudes. The rim of Humboldt is low, worn, and irregular in outline. The central peak forms a range on the crater floor. The floor surface contains a network of clefts forming a pattern of radial spokes and concentric arcs. There are also some dark patches located northwest, and southeast. There is a chain of craters as long as the crater is wide. This formation is designated

worksheet

LAB ACTIVITY PART 4

Name ______________________________________

Image comparisons: looking for water

In this activity, you will be making comparisons between permanently shadowed areas and areas that are exposed to sunlight during part of the Moon's rotation.

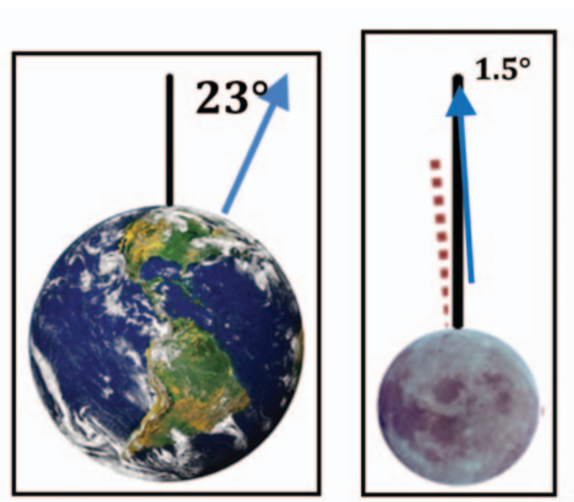
Materials:

- Worksheets that show 2 different images: the lunar south pole, and a sunlit area of the Moon (on next page).

Background Information:

The Moon is a unique environment because it has no atmosphere. As a result, the Moon is a relatively dry and hostile environment. During the daytime on the Moon, the temperatures can soar to 123°C, and at night can dip as low as -233°C. Water freezes at 0°C and boils at 100°C, so as you can see, this environment makes it difficult for water to remain on the surface for any length of time.

The only way water could be found in such a barren environment would be if it were sheltered from the elements. Make a list of the places you might find water on the Moon:



Like other planetary bodies in the solar system, the Moon has an axis. The Moon also rotates on this axis; however its axial tilt is much different than Earth's. Earth has an axial tilt of 23° while the Moon only has an axial tilt of 1.5°. Because the Earth is tilted at such an angle, we experience seasons and both the North and South poles receive direct sunlight at least for part of the year. This causes the poles to expand and contract with the changing of the seasons.

The Moon on the other hand rotates almost straight up and down, meaning it hardly has any axial tilt. Because of this, parts of the poles have never seen the light of day! This creates an interesting environment. In a place that experiences 350° temperature differences between night and day, the lunar poles remain VERY cold.

worksheet

Now that you have made a list of the areas that may provide an environment for water, let's compare a couple of images of the surface of the moon that could help identify locations for finding water.

Compare the two images below. What is the same and what is different?

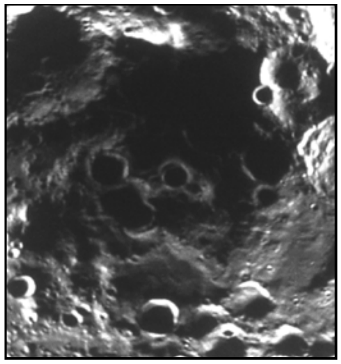


Image 1—south pole

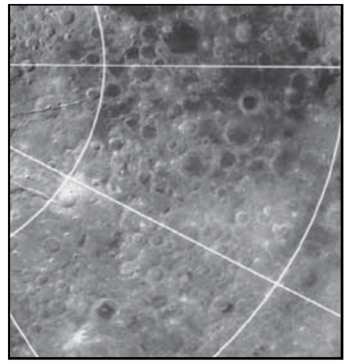


Image 2—sunlit area

Same:

Different:

worksheet

LAB ACTIVITY PART 5

Looking for Water

Name ______________________________

Next, we will test your skills on being able to find “anomalous” craters at the north pole of the Moon.

Materials:

- Red and Blue dry erase markers
- “Mini-SAR CPR map” image (see supplemental materials section)
- “Clementine Mosaic North Pole” image (see supplemental materials section)
- Clear overhead transparency
- Tape (blue painter’s tape works well)
- Lunar Landforms and Associated Images sheets (see supplemental materials section)

Procedure:

1. Similar to what you did in the previous activity, compare the two images “Mini-SAR CPR map” image and the “Clementine Mosaic North Pole” image.
2. List three surface features you can see in the Mini-SAR image that you can’t see in the black and white mosaic image (pay no attention to the circles or arrows in the Mini-SAR image).
    a.

    b.

    c.
3. Next, place a clean overhead transparency over the image “Mini-SAR CPR map” and one over the “Clementine Mosaic North Pole” image. Tape the corners with clear tape so the transparency doesn’t move.
4. Notice that in the “Mini-SAR CPR map” image, numerous craters are circled and some have arrows pointing to them.
5. Compare this image with the “Clementine Mosaic North Pole” image.
6. Identify five circles in the “Mini-SAR CPR map” and match them with the craters in the “Clementine Mosaic North Pole” image.
7. On the “Mini-SAR CPR map” use a blue dry erase marker to indicate “different” or “anomalous” craters, or craters that should look rough (white) but show up on the visible image as “smooth”, and use a red dry marker to indicate craters that don’t show any unusual pattern.

(continued on next page)

worksheet

8. Of the five craters you chose, describe what you found and your reasons:

Assessment:

As you have seen, utilizing radar data helps scientists to view hidden areas of the surface of a planet. Discuss with students:

- What are some additional ways planetary scientists might use radar imagery with the analysis of a planet?
- Are there other disciplines in science (biology, meteorology, oceanography, etc.) that can utilize radar images? In what ways?
- In your own words, can you define what is meant by high CPR and low CPR?

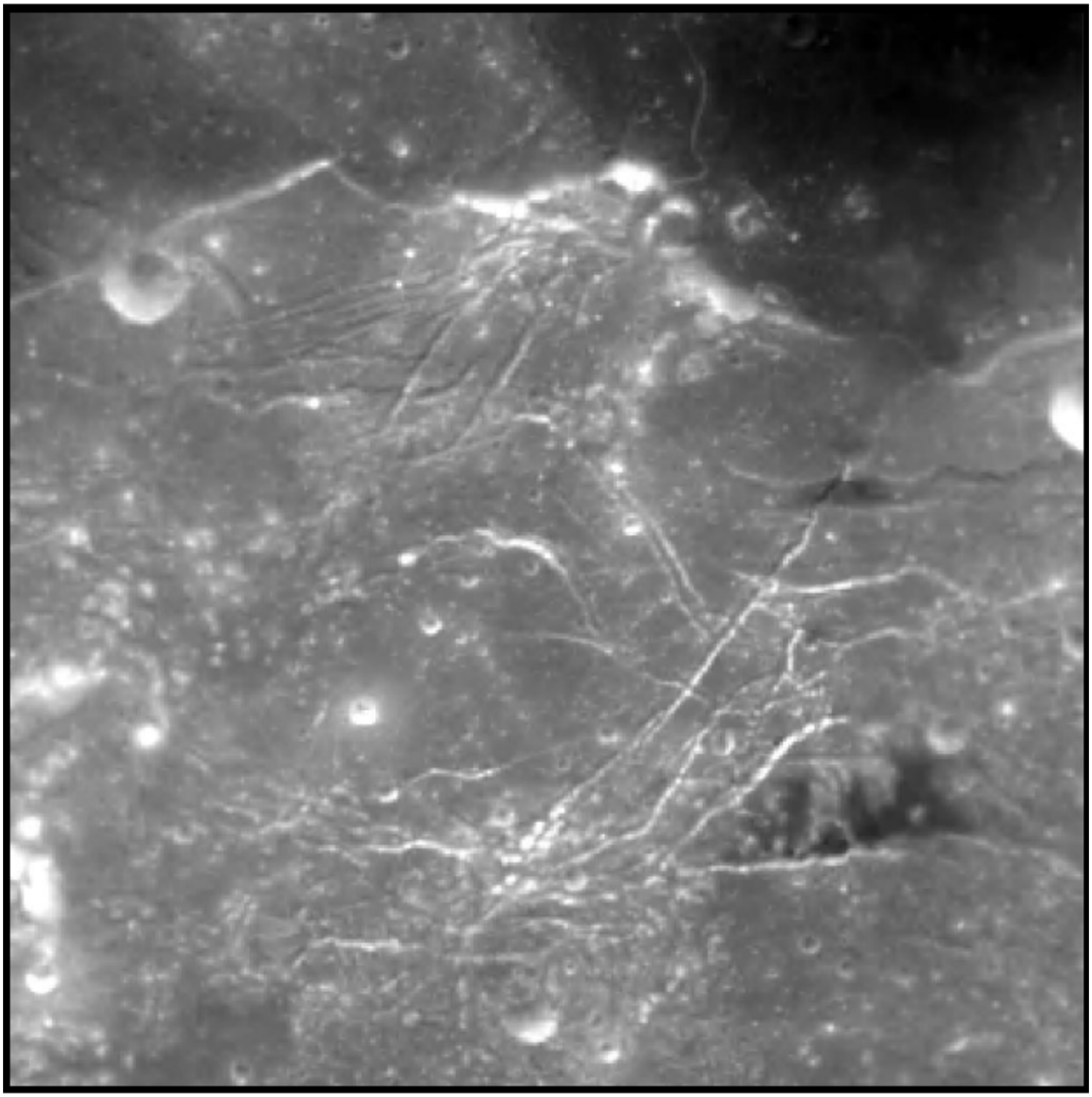
Extension Activities:

Use Google Earth or Google Maps in conjunction with NASA's "Visible Earth" (http://visibleearth.nasa.gov/) website to conduct additional analyses of images. Once on the "Visible Earth" website, follow the steps below to find radar images:

- Go to "sensor".
- Scroll down to the bottom and select "SIR-C/X-SAR." This will give you a list of the images that were taken using SIR-C radar imaging instrument. Have students identify where this image was taken, then locate it via Google Earth or Google Maps. Have the students compare both images and make notes as to what they can see or not see comparing radar and visible images of the same location.

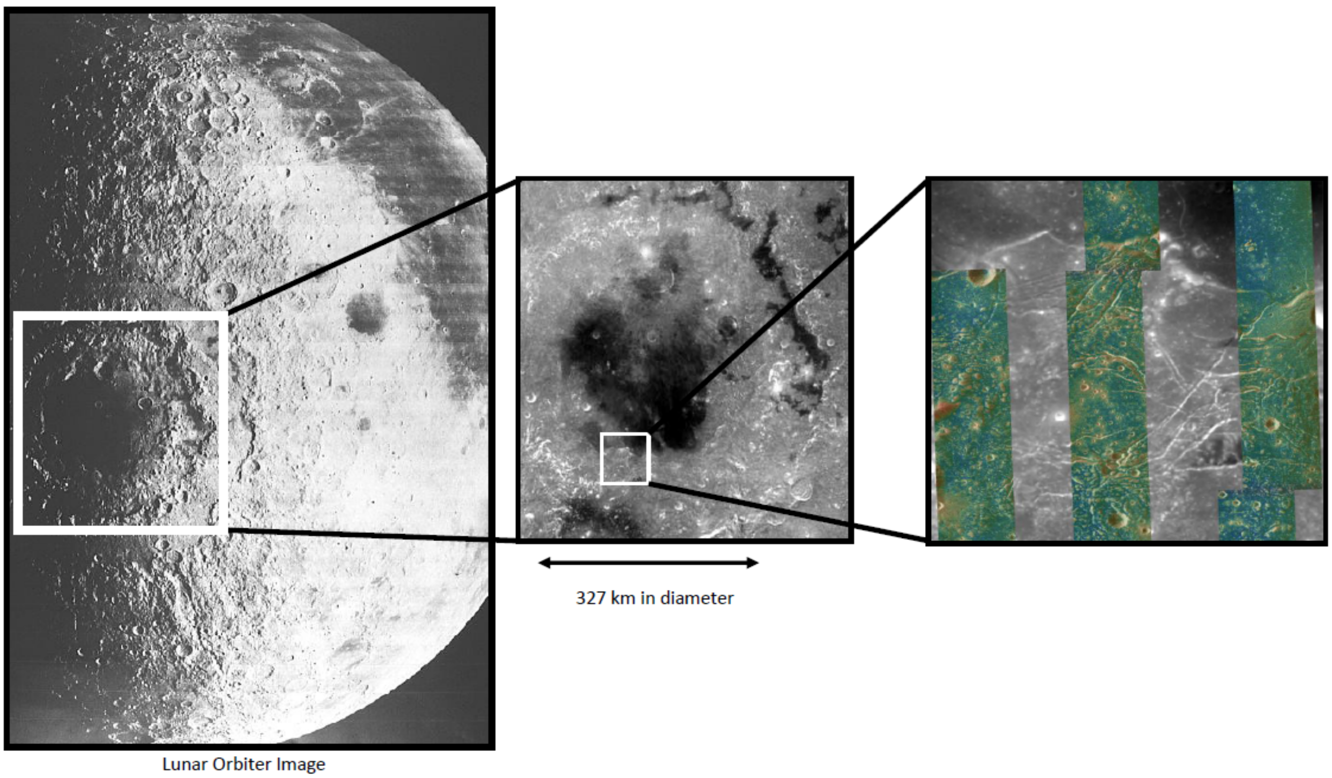
SUPPLEMENTAL IMAGES/ MATERIALS/ RESOURCES:

Orientale Basin

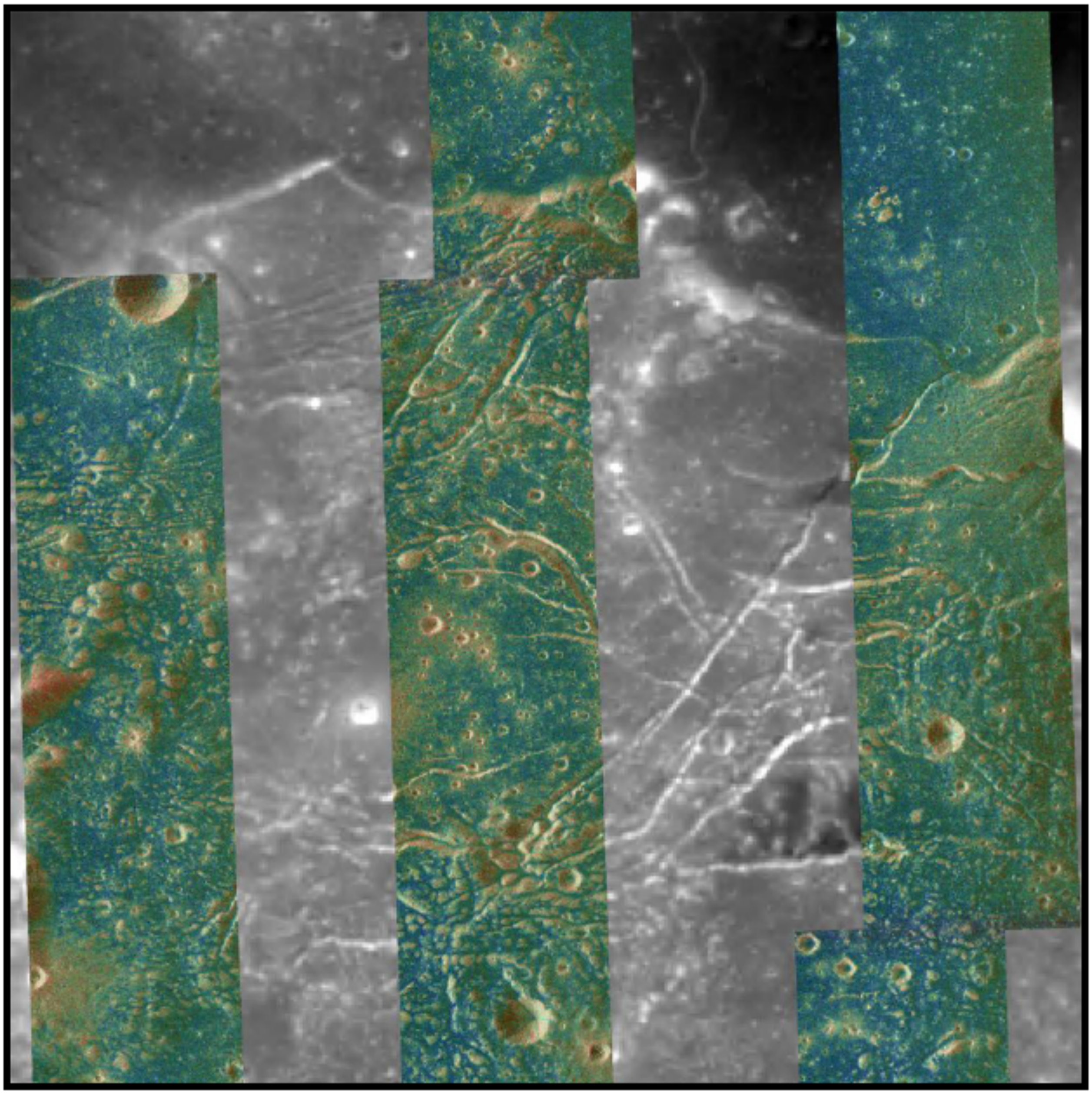


Context for Orientale Basin

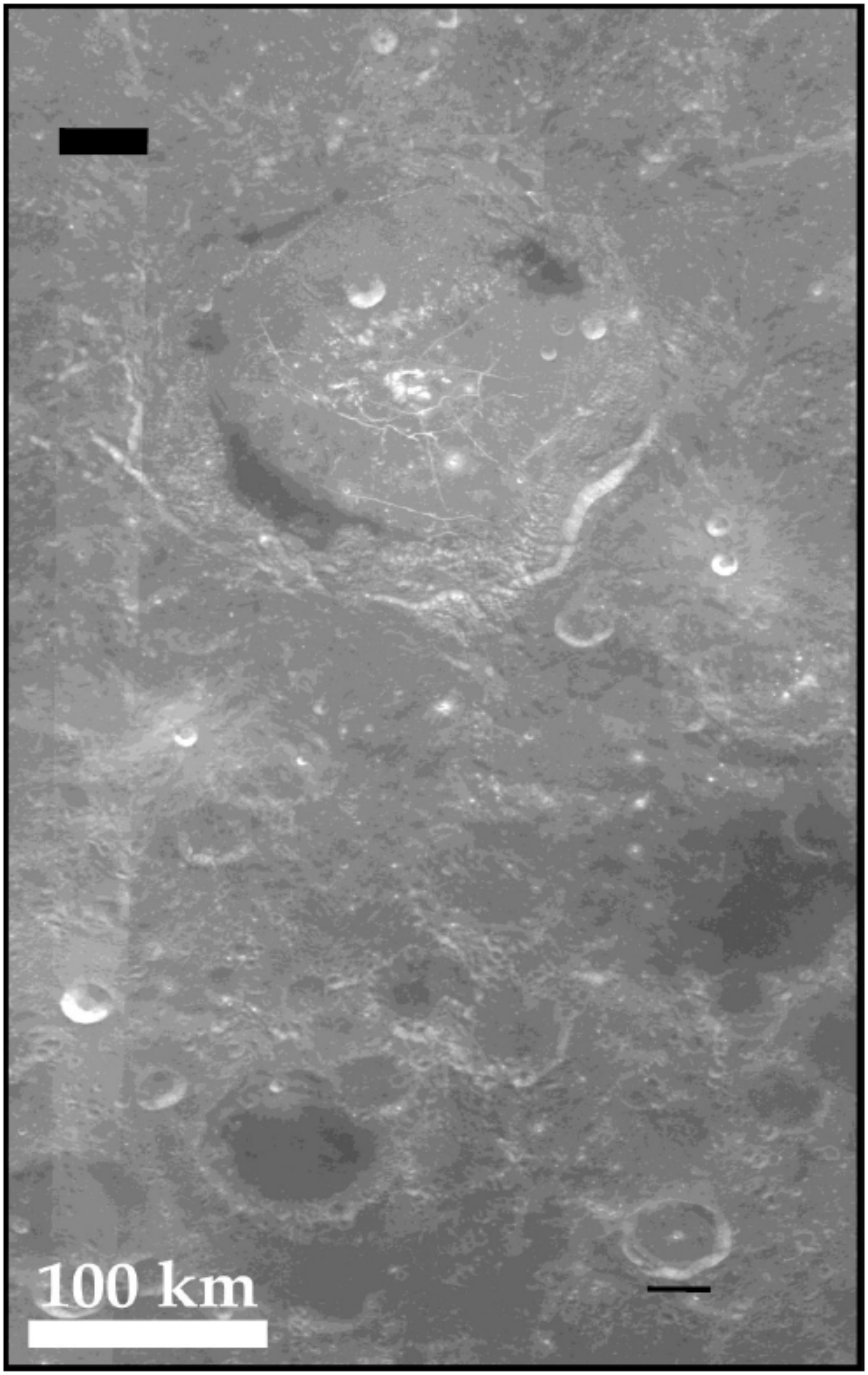
Like a target ring bull's-eye, the Mare Orientale is one of the most striking large-scale lunar features. Located on the Moon's extreme western edge, this impact basin is unfortunately difficult to see from an earthbound perspective.



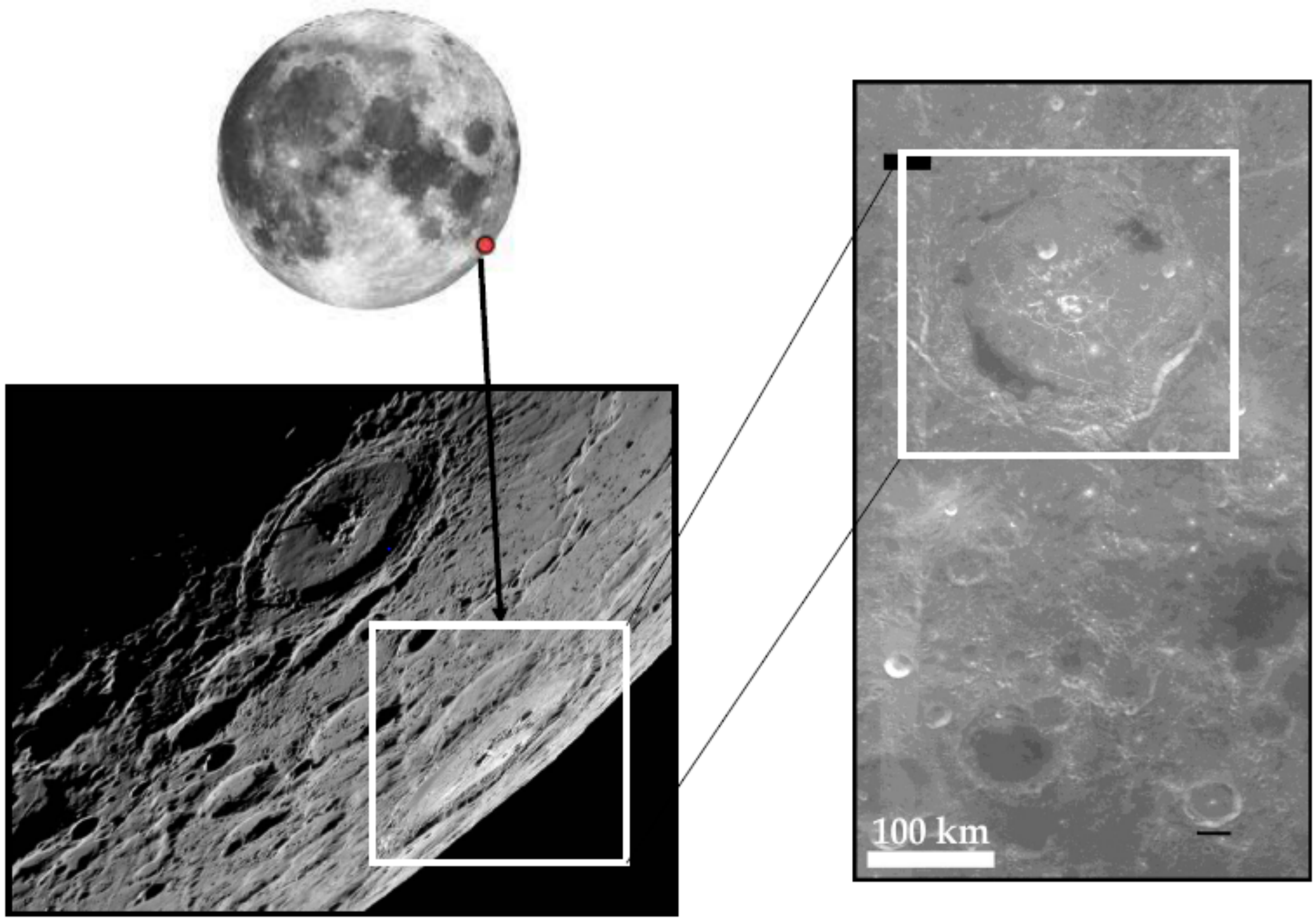
Clementine Mosaic of Orientale Basin with Mini-RF Overlay



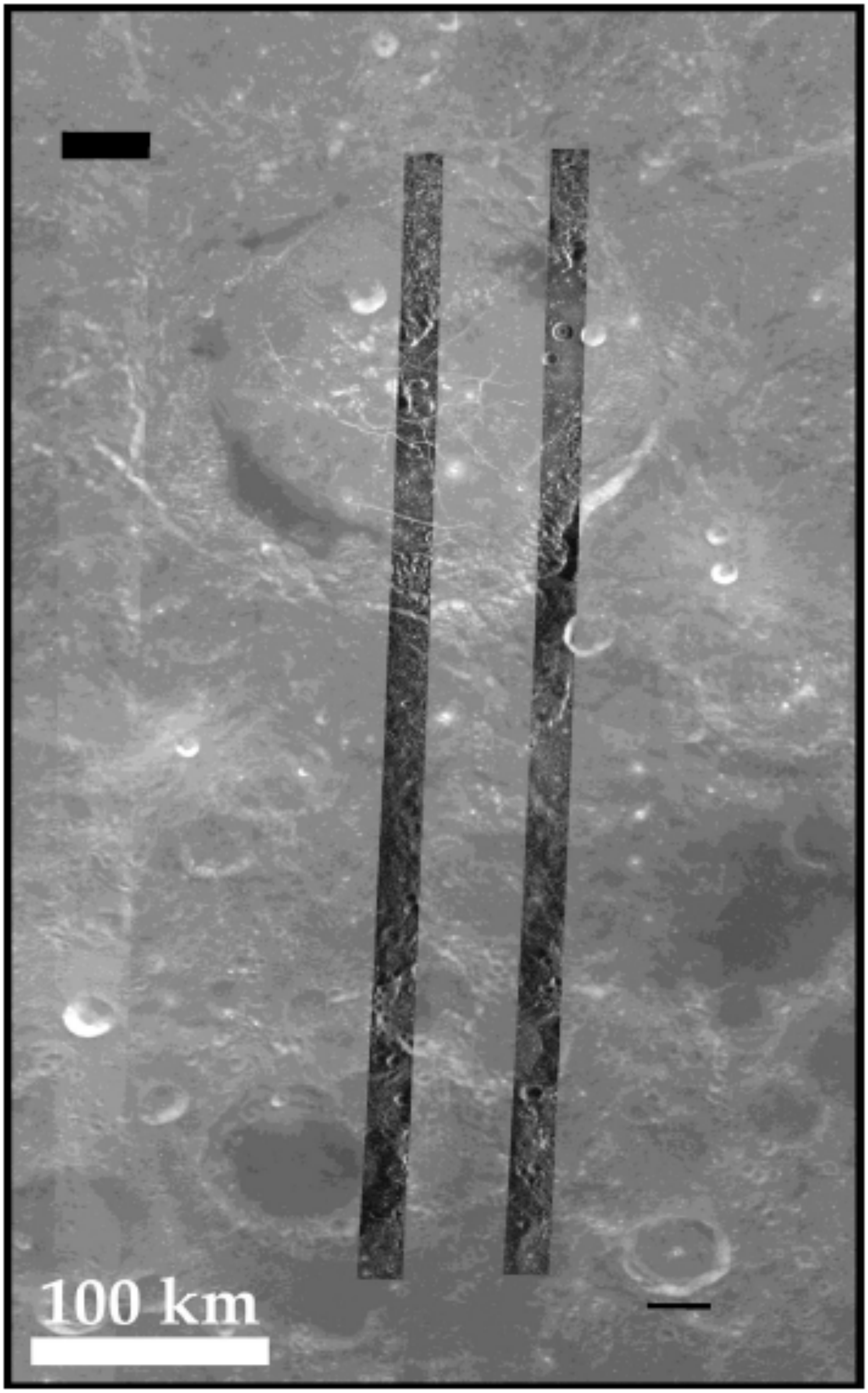
Clementine Mosaic—Humboldt Crater



Context for Humboldt Crater



Clementine Mosaic with Min-RF overlay—Humboldt Crater



Mini-RF data Magnified—Humboldt Crater

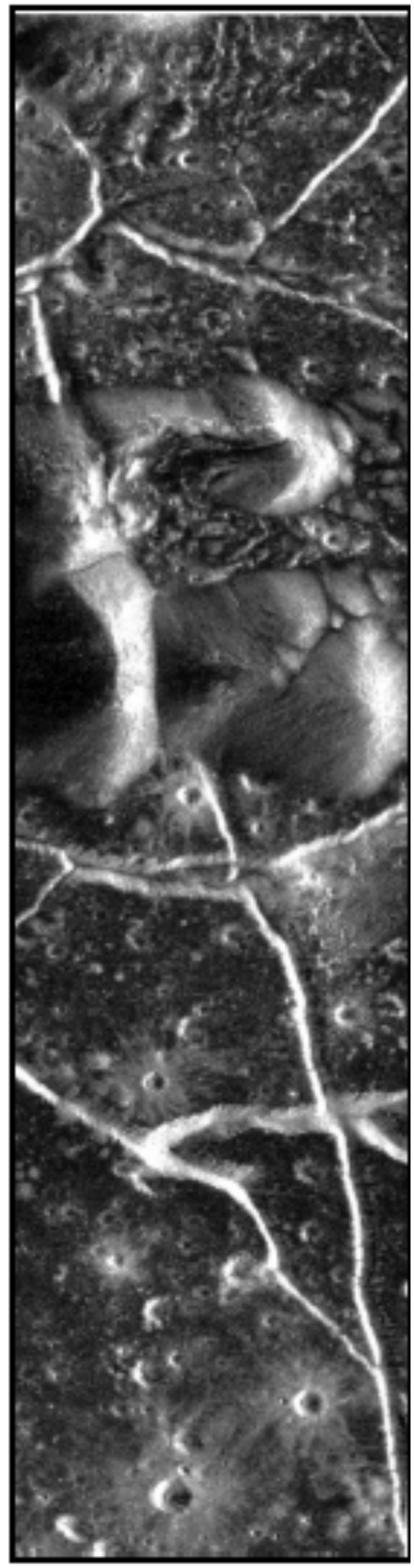
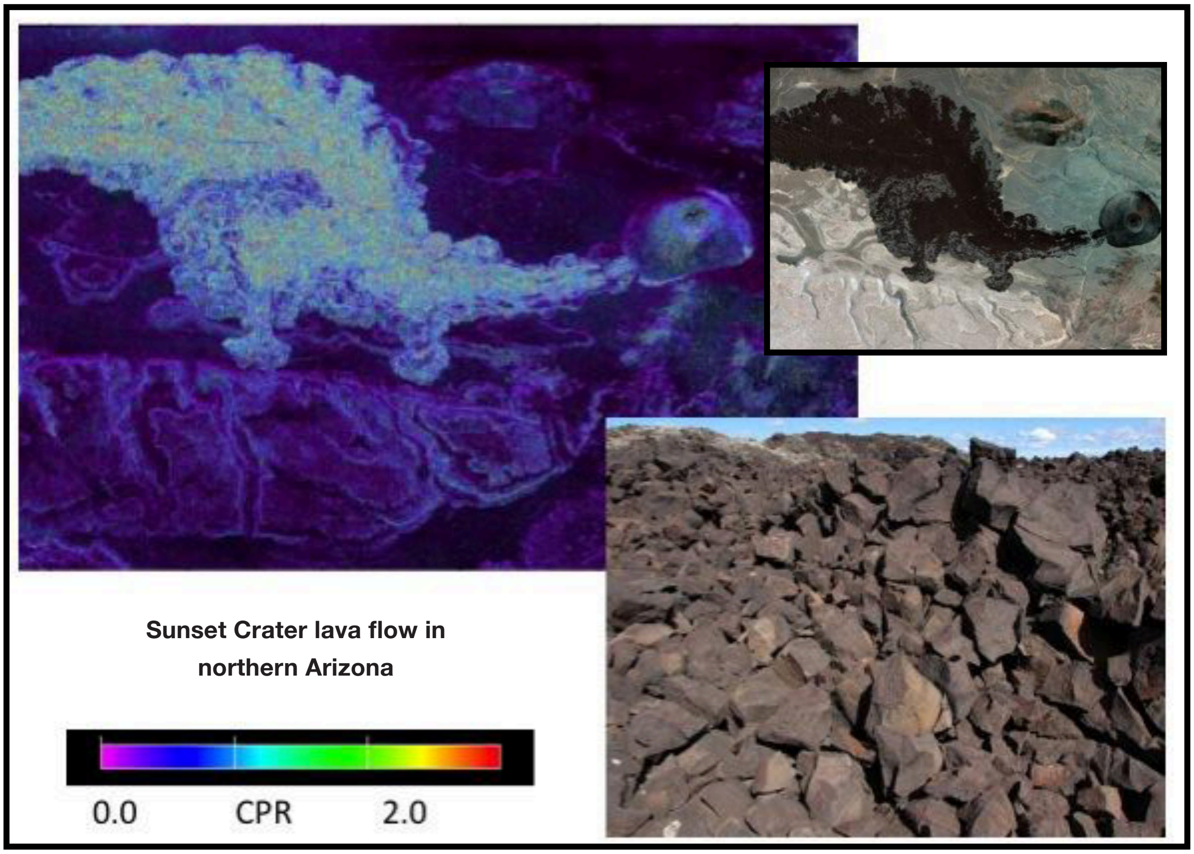


Image Interpretation



Sunset Crater lava flow in northern Arizona

The image above shows a visible image on the right, and a false-color radar image to the left. False-color simply means that scientists have to add color to the data in the image so they can understand what the information is telling them.

It is difficult to tell in the visible image if the dark area is rough or smooth. But, using radar, we can see using the colored CPR bar at the bottom the surface is fairly rough. We can also confirm this in the close-up image of the same region in the lower right. This is a good example of remote sensing, a technique in which scientists, much like detectives, use satellite images in combination with surface images to piece together clues about a region without actually visiting the site.

Lunar Landforms Information Sheet

Use this sheet to identify the different types of features found on the Moon:

Central Crater Uplift: mountain in the center of large (greater than 40 kilometer in diameter) impact craters.

Cinder Cone: a low, broad, dark, cone-shaped hill formed by an explosive volcanic eruption.

Crater Ejecta: material thrown out from and deposited around an impact crater.

Dome: a low, circular, rounded hill, which is suspected to be a volcanic landform.

Highlands: the highlands appear as bright areas of the Moon. The highlands are comprised of countless overlapping craters (ranging from 1 meter to over 1000 meters) that formed when meteorites crashed into the Moon.

Impact Crater: a roughly circular hole created when something, such as a meteorite, struck the Moon's surface.

Lava Flow: a break out of magma from underground onto the surface.

Maria: areas that formed when lava flows filled in low places. The low places are mostly inside huge basins, which were formed by large meteor impacts. The maria cover 16% of the Moon's surface.

Multi-Ringed Basin: huge impact crater surrounded by circular mountain chains.

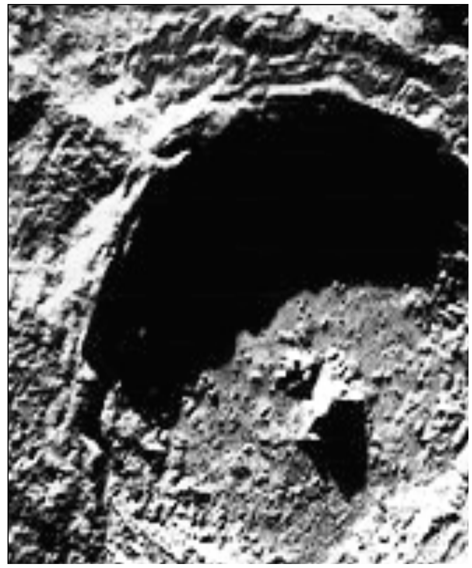
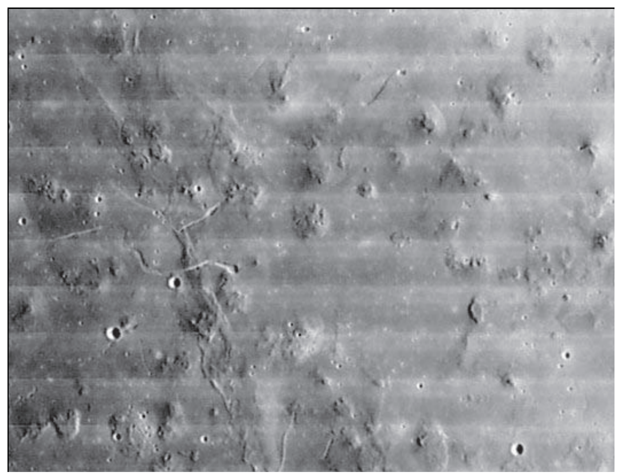
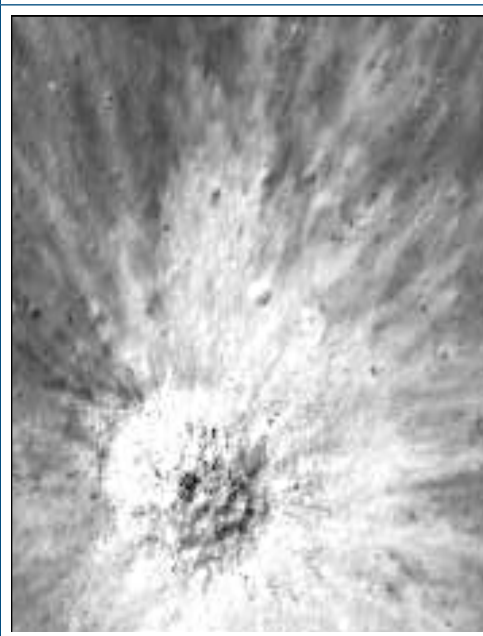
Ray: bright streak of material blasted out from an impact crater.

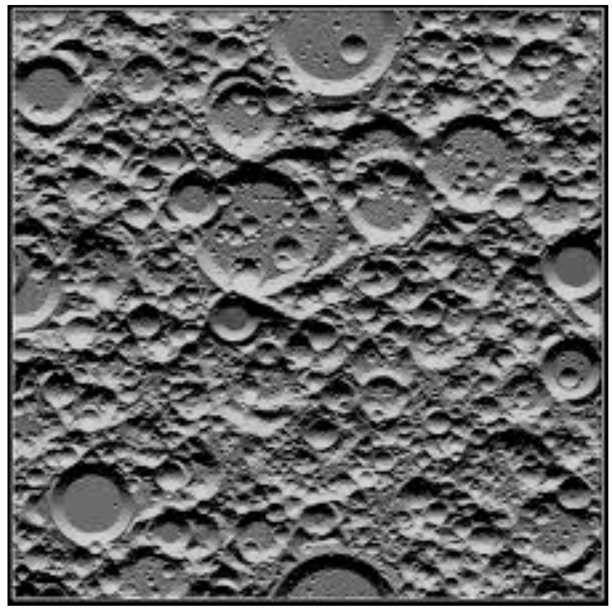
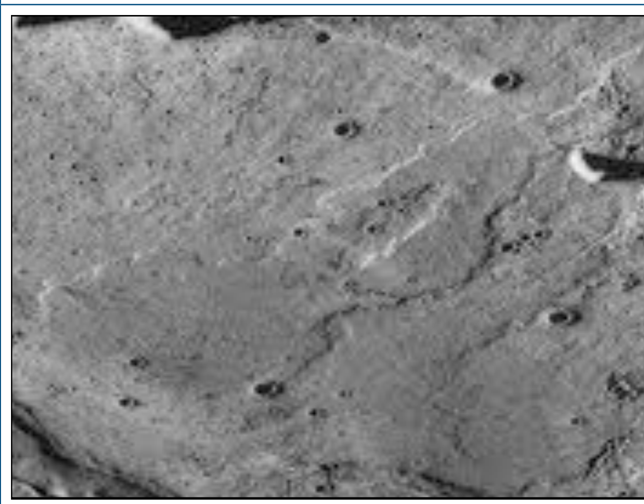
Rille: a channel in the lunar maria formed by an open lava channel or a collapsed lava tube.

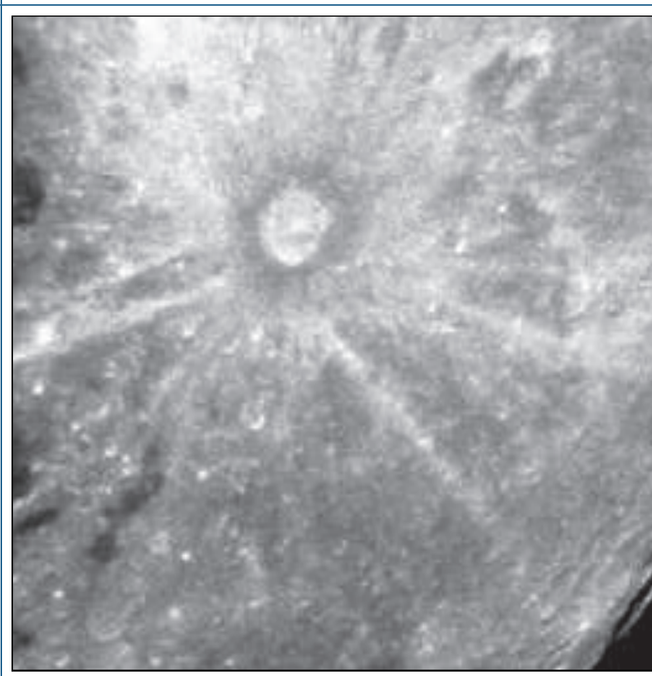
Terraced Crater Walls: steep walls of an impact crater with "stair steps" created by slumping due to gravity and landslides.

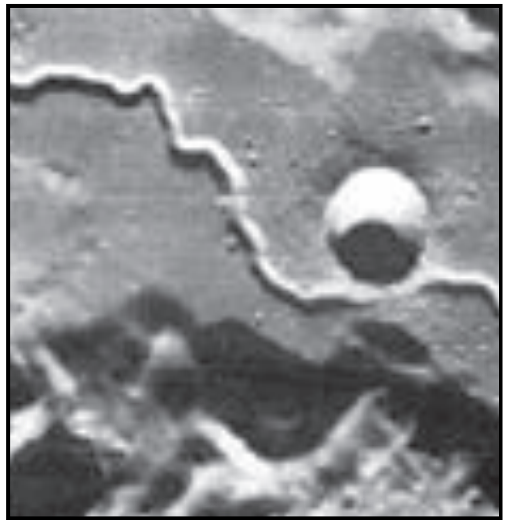
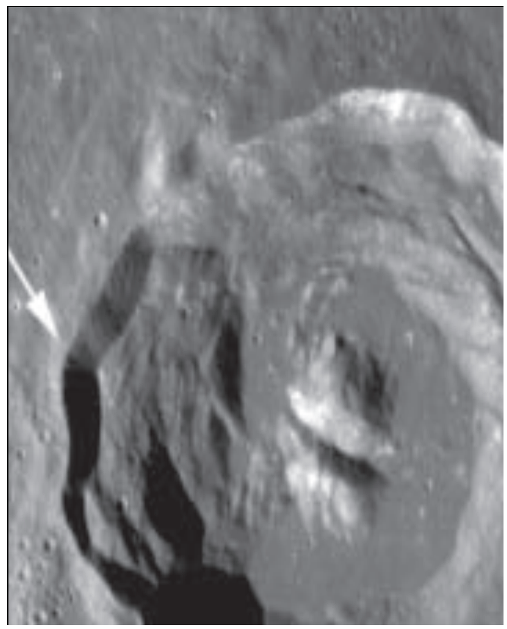
Wrinkle Ridge: a long, narrow, wrinkly, hilly section in the maria.

Lunar Landform Definitions and Associated Images

Definition	Picture example
Central crater uplift: Mountain in the center of large (greater than 40 kilometer in diameter) impact craters.	
Cinder cone: A low, broad, dark, cone-shaped hill formed by an explosive volcanic eruption.	
Crater ejecta: Material thrown out from and deposited around an impact crater.	

Dome: A low, circular, rounded hill which is suspected to be a volcanic landform.	
Highlands: The highlands appear as bright areas of the Moon. The highlands are comprised of countless overlapping craters that formed when an impactor crashed into the Moon.	
Impact crater: A roughly circular hole created when something, such as a meteorite, struck the Moon's surface.	
Lava flow: A break out of magma from underground onto the surface.	

Maria: Areas that formed when lava flows filled in low places. The low places are mostly inside huge basins which were formed by large meteor impacts. The maria covers 16% of the Moon’s surface.	
Multi-ringed basin: Huge impact crater surrounded by circular mountain chains.	
Ray: Bright streak of material blasted out from an impact crater.	

Rille: A channel in the lunar maria formed by an open lava channel or a collapsed lava tube.	
Terraced crater walls: Steep walls of an impact crater with “stair steps” created by slumping due to gravity and landslides.	
Wrinkle ridge: A long, narrow, wrinkly, hilly section in the maria.	

Mini-SAR CPR map